Acute Kidney Injury
in the ICU
Sept 8, 2016

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“Oh the places we’ll go…”

- Definition
- Epidemiology
- Risk Factors, Etiology, and Pathophysiology
- Conservative Management
- Contrast Nephropathy
- Renal Replacement Therapy
Definitions

(Cruz, Ricci et al. 2009)
“A Rose By Any Other Name...”

Large New Zealand Cohort.
Similar Incidence of AKI between categories.

Perhaps more importantly, the Mortality Odds Ratio between the categories was very similar

(Bagshaw, George et al. 2008)
Take Home Point #1

Can stratify AKI according to degree of injury; which system you use probably doesn’t matter.
Breadth of the Problem

AKI Among All Hospitalized Patients:: 5 - 7.5%

AKI Among ICU Patients:: ?

USRDS database
Breadth of the Problem

Degree of Acute Kidney Injury in ICU

UPMC had 7 ICUs
- Collected data from 5383 patients
- Excluded those who went on to need HD

- No AKI: 33%
- Risk: 12%
- Injury: 27%
- Failure: 28%

(Hoste, Clermont et al. 2006)
AKI also statistically changes the prognosis of patients in the ICU...

The risk of death for all ICU patients: ~8-19%

Risk of death for ICU patients with AKI: 25-40%

Risk of developing HD requirement: 5-6%

Risk of death for patients requiring HD: 50-80%
Depth of the Problem

And if they survive the hospital?

This is based on Medicare data, so the included patients had AKI coded at the time of discharge.
Take Home Point #2

AKI is common, and may significantly impact mortality both in and after the hospitalization.

Alternatively, it may be a marker for mortality “susceptibility”
So what causes it and how?

(Nash, Hafeez et al. 2002)
Etiology - Risk Factors

- Old Age (> 75 yrs)
- Chronic kidney disease (eGFR < 60 mls/min/1.73m²)
  - The worse your function is at baseline, the greater the risk
- Cardiovascular Disease
  - CHF
  - PVD
- Liver Disease
- Diabetes Mellitus

Note that by the time you all meet these folks, these risks are non-modifiable
Etiology – Making Urine

- 25% of all Cardiac Output (CO) goes straight to the kidney.
- Blood moves through the arteriolar system into the glomeruli.
- The glomerular filtration barrier allows for production of urinary filtrate.
- The tubules modify that filtrate by reabsorbing things of value and secreting things too large to be filtered.
- Urine moves into the renal pelvis, through the ureters and into the bladder.
Etiology - Broad Strokes

1. Prerenal (Hemodynamic Causes): Anything that disturbs blood flood to the glomeruli.

2. Intrarenal: Anything that disturbs the glomerular or tubular architecture.

3. Postrenal: Acute obstruction with increased pressure referred back to Bowmans Space.
Etiology – Prerenal AKI (40-60%)

Pump Problems:
- Left Heart Failure
- Right Heart Failure

Vascular Occlusion/ Afferent Arteriolar:
- Renal Artery Embolism
- Renal Artery Stenosis
- Afferent arteriolar vasoconstriction

Distributive Physiology:
- Septic Shock
- Nephrotic Syndrome
- Hepatorenal Syndrome

Hypovolemia
Etiology – Intrarenal AKI (20-40%)

Glomerulonephritides
• Too many to list

Vascular Diseases
• Thrombotic Microangiopathy
• HUS
• HTN, DMII
• Calcineurin Inhibitor Toxicity

Tubular Diseases
• Acute Tubular Necrosis
• Allergic Interstitial Nephritis
• Direct Tubular Toxins
• Tumor Lysis Syndrome
Etiology – Obstructive (<10%)

High Obstruction (Renal Pelvis)
• Papillary Necrosis
• Struvite Stones

Bilateral Ureteral Obstruction
• Nephrolithiasis
• Extrinsic Compression

Bladder Outlet Obstruction
• Prostatic Disease
• Bladder CA
• Ureteral diseases
Great... I Have Another Stupid List

The question immediately becomes, how do you parse through it? How do you meaningfully narrow it into something intervenable?

1. *History and physical examination*
2. Identify your toolset and apply deliberately...
Evaluation of Kidney Function...

Clearance:
1. Serum Cr (Cystatin C)
2. 24 hour Cr Clearance

Perfusion:
1. Urine Output

Tubular Function:
1. Urinalysis
2. FENa
3. Urine Osmolarity

Structural Injury:
1. Renal Ultrasound
2. Urinalysis
3. Proteinuria quantification
Serum Creatinine

- MDRD is meaningless in AKI
- A small change in Creatinine is VERY meaningful

(HP Lefebvre 2016 International Renal Interest Society)
Fractional Excretion

Fraction Excretion of Sodium (or Urea) gives you insight into the *avidity* of the kidney for solute.

A highly avid kidney is trying to reclaim solute (and therefore water) maximally...

The kidney is “thirsty”...
Fractional Excretion

Interpretation, simplified:
Less than 1% sodium excreted (or 35% Urea) means the kidney is working as hard as it can to conserve solute and water.

Prerenal Etiology

Above 1% = Something else
Fractional Excretion

$$FE_{Na} = \frac{Urine_{Na} \text{Plasma}_{Cr}}{Urine_{Cr} \text{Plasma}_{Na}} \times 100$$

Conceptually:

Result shows the percentage of filtered sodium that is excreted. Looked at conversely – it shows how much sodium is conserved. More Conservation = Higher Avidity
Fractional Excretion - Pitfalls

FENa is most useful early in ICU stay:
1. AKI with oliguria
2. Minimal background CKD
3. Absence of Metabolic Alkalosis
4. Absence of nonreabsorbable ions
5. No diuretics

FEUrea has similar restrictions, except, diuretics less of an impact.

(Nguyen, Maynard et al. 2009)
Proteinuria is a marker of glomerular breakdown.

In AKI, some small amount of proteinuria is “acceptable”

If large protein losses, this suggests glomerular disease...
<table>
<thead>
<tr>
<th></th>
<th><strong>Prerenal AKI</strong></th>
<th><strong>ATN</strong></th>
<th><strong>AIN</strong></th>
<th><strong>Postrenal AKI</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Etiology</strong></td>
<td>Shock, hypovolemia</td>
<td>Ischemia</td>
<td>Anaphylaxis, Allergic Drug Rx</td>
<td>Obstruction</td>
</tr>
<tr>
<td><strong>Urine Na</strong></td>
<td>&lt; 20</td>
<td>&gt; 20</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>FeNa</strong></td>
<td>&lt; 1%</td>
<td>&gt; 1%</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Urine osms</strong></td>
<td>Concentrated</td>
<td>Isoosmolar</td>
<td>Isoosmolar to dilute</td>
<td>Iso to dilute</td>
</tr>
<tr>
<td><strong>Urinary sediment</strong></td>
<td>Hyaline casts</td>
<td>Muddy Brown Casts</td>
<td>White Cells, White Cell Casts, maybe eos</td>
<td>Variable</td>
</tr>
<tr>
<td><strong>Renal U/S</strong></td>
<td>NI kidneys</td>
<td>NI or echogenic</td>
<td>Echogenic</td>
<td>Dilated urinary space</td>
</tr>
</tbody>
</table>
Take Home Point #3

Develop a differential based on the available history, then refine with deliberate testing...
Conservative Management

Prerenal AKI

Step 1: Identify Underlying Cause and Treat

Step 2: Attempt to perfuse glomeruli and tubules to prevent development of ATN.

a. Fluid challenge
   - Crystalloid: 15-30mL/kg x1, repeat based on exam and monitoring
   - Colloid: No proven benefit (though...)

b. If clinically volume overloaded
   - Consider Lasix challenge: one dose of 1mg/kg

c. Uncertainty?
   - Evaluate with CVP, echo for IVC fullness
   - Empirical trial of a or b
Conservative Management

### Intrarenal AKI

<table>
<thead>
<tr>
<th>ATN: Challenging. No “Magic Bullet”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treat the cause! Support:</td>
</tr>
<tr>
<td>- Optimize hemodynamics</td>
</tr>
<tr>
<td>- Ensure volume replete</td>
</tr>
<tr>
<td>- Follow electrolytes</td>
</tr>
<tr>
<td>- Treat aberrancies as they arise</td>
</tr>
<tr>
<td>- When the time comes, initiate hemodialysis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AIN: Challenging. Steroids might benefit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support:</td>
</tr>
<tr>
<td>- Optimize hemodynamics</td>
</tr>
<tr>
<td>- Remove the offending agent.</td>
</tr>
<tr>
<td>- Support with Hemodialysis if needed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Glomerular Diseases: Challenging. Varies according the specific cause.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thankfully rare in the ICU. Consult Nephrology for help.</td>
</tr>
</tbody>
</table>
Conservative Management

Obstructive Nephropathy
Relieve the obstruction.
Take Home Point #4

Narrow the differential, treat what you can, support through what you can’t.
A word about Contrast Nephropathy

Common in certain ICU settings.

Classically:

- Risk Factors
- Exposure
- AKI
- Recovery

2% of the general population develop AKI, up to 50% of people with multiple comorbidities.
Contrast Nephropathy

Focus on prevention:

Essentially data has shown that only intravascular volume seems to matter.

No benefit (or harm) for NAC, nor alkalinization (add’l slides)
Take Home Point #5

The only proven intervention for Contrast Nephropathy is pre-procedural euvoolemia.
When to dialyze?
Decision for RRT

A – Worsening Acidemia
E – Electrolytes. Namely Hyperkalemia
I – Intoxication. Toxic ingestion especially
O – Volume Overload.
U – Uremia (which isn’t azotemia...)
Decision for RRT

Decision to start hemodialysis is highly dependent on the details of the case.

Initiation Strategies for Renal-Replacement Therapy in the Intensive Care Unit

One of Many...

(Gaudry, Hajage et al. 2016)
Decision for RRT – personal word

Dialysis is a significant threshold.

Given that it generally signifies a worsening underlying process, it provides an opportunity to revisit goals of care.
Take Home Point #6

No data on *when* to start HD in a patient in ICU with AKI. Seek guidance of Nephrologist, but *leverage your opinion.*
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Questions?

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References


